

Replay to "Comment on 'Screening in gated bilayer graphene' "

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Abstract

We discuss the physics of the tunable bandgap in bilayer graphene with the gate voltage and doping. A comparison with experimental data obtained by Kuzmenko et al [Phys. Rev. B **80**, 165406 (2009)] demonstrates the good agreement.

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Bilayer graphene is widely known (see, for instance, [1]) as a tunable bandgap semiconductor: its band structure depends on the external gate voltage and doping. This phenomenon is promising for application. From the theoretical point of view, the problem can be considered as follows. Two parameters, the chemical potential and the bandgap, should be determined in an external electric field, normal to the bilayer surface. Then, we have a typical variation problem. As the effect of doping was not considered in the previous publication [2], we solved this problem [3] with the method of the total energy minimization. The problem was considered as well in Ref. [4] within DFT calculations.

The result [3] does not coincide with Ref. [2] even for the case of undoped bilayer graphene. The reason of the disagreement is in the definition of the ground state of the system. In Ref. [3], we assume that the ground state is realized in the undoped pristine bilayer where the chemical potential is situated between two nearest bands. Therefore, at doping or gate voltage, we take into account only the excitation of holes in the valence band or electrons in the conduction band. Of course, this concept takes implicitly into account electron-electron interactions. In contrast to this, while considering the effect of the external electric field in Refs. [2, 5], the energy of excitations in the completely filled deep band is included in the total energy. First of all, such a consideration, involving the large contribution of completely filled band, has no need in the variation method in contradictions with the statement of the paper [5]. The method used in [5] gives only the evident electrostatic condition, Eq. (13). This condition is naturally applied from the outset in Ref. [3] to construct the total energy. Second, the including the energy of the deep states violates the concepts of the normal Fermi liquid, according to which the responses of the Fermi liquid are resulted from the neighborhood of the Fermi surface.

Several statements of Ref. [5] are incorrect, including for example, the attempt [see, paragraph after Eq. (13)] to extract the direction of the electric field from the scheme in Fig. 3 of Ref. [3]. The authors of Ref. [5] have forgotten that the electric field is determined by carriers as well as dopant which does not shown in the scheme. In fact, two possible directions of the electric field are consistent with two signs in Eq. (14) of Ref. [3] and the solution to this equation is found only at the certain sign that chooses the field direction.

The results of the Ref. [5] differ from the previous paper [2] only in the involving of dopant. The authors statement before Eq. (2) is wrong, no such formula was derived in their paper [2]. The authors of the paper [5] do not present any comparison of their results

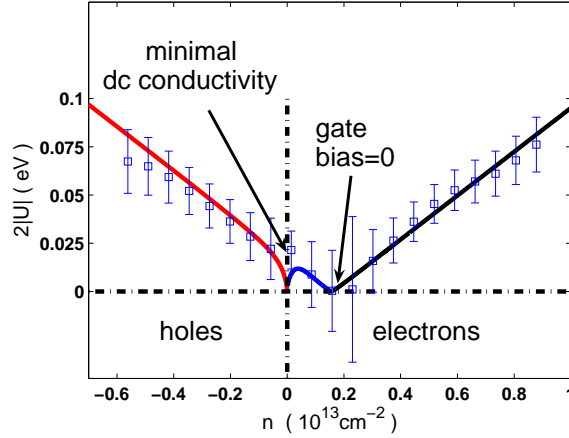


FIG. 1: The gap in eV versus the carrier concentration for the electron doping with the concentration $N_2 = 0.78 \times 10^{12} \text{ cm}^{-2}$ (our theory); the positive (negative) values of n correspond to the electron (hole) conductivity; squares are experimental data [6].

with experiments [6–8] referring the disorder as a reason of possible disagreement of their theory with experiments. For definiteness, we compare in Fig. 1 the result of Ref. [3] with experimental data from Ref. [6]. The complicated behavior near low carrier concentrations is connected with the effect of doping. Other result of the doping, the asymmetry at the electron-hole sides, is evident from the figure.

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